E

DAY 2:

THE EXPERIMENT ON RED BEADS

NB If you are viewing Day 2 on-screen then you may find that a few of the more ancient images are somewhat distorted. The images concerned were mainly scans of photocopies made from overhead projector transparencies shown to delegates at some of my seminars. To the best of my very limited knowledge about such matters, the nature and extent of this problem seems to largely depend on the size of the screen and/or the version of the Adobe Acrobat Reader that you are using. Usually, but not always, the distortion is less on printed copies than on-screen.

If you have more expert knowledge than I do about such problems and can offer me some help on how to overcome them, do please contact me on at henryneave@sky.com.

DAY 2: THE EXPERIMENT ON RED BEADS **(Stats-level 0 only)**

(9.15am – 12.45pm; 1.45pm – 4.45pm)

Run charts (p 1) — *contains Pause for Thought 2–a*

Introduction to the Red Beads Experiment (p 5) — *contains Pauses for Thought 2–b and 2-c*

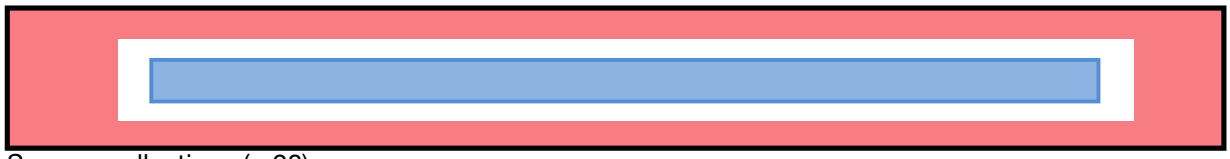
A brief overview (p 9) — *contains Pause for Thought 2–d*

"Analysis" of the results (p 12)
Our first control chart (p 14) — *contains Pause for Thought 2–e*

The truth, the whole truth, and nothing but … (p 17)

Your turn (p 22)
Activity 2–f (p 22 *[WB 14]*)

Read *DemDim* Chapter 6 (p 27)



Some recollections (p 28)

Activity 2–g (p 32 *[WB 20]*)

Major Activity 2–h (p 38 *[WB 26]*)

Postscript (p 42); "Wrap-up brief"; "Out-of-hours" note (p 43)

NB In the text, the clock icons for **Stats-level 0 only** *are on the left-hand side of the pages.*

DAY 2: THE EXPERIMENT ON RED BEADS (Stats-levels 1–3)

(9.00am – 12.45pm; 1.45pm – 5.00pm)

Run charts (p 1) — *contains Pause for Thought 2–a*

Introduction to the Red Beads Experiment (p 5) — *contains Pauses for Thought 2–b and 2-c*

A brief overview (p 9) — *contains Pause for Thought 2–d*

"Analysis" of the results (p 12)
Our first control chart (p 14) — *contains Pause for Thought 2–e*

The truth, the whole truth, and nothing but … (p 17)

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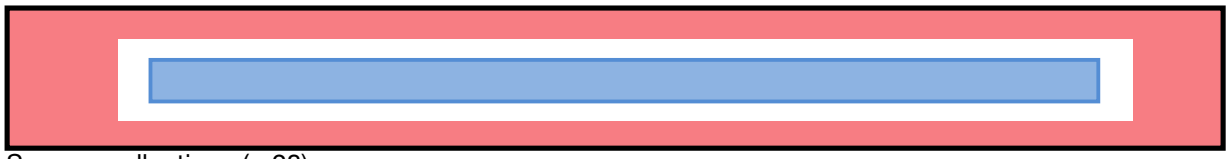

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Major Activity 2–h (p 38 *[WB 26]*)

Postscript (p 42); "Wrap-up brief"; "Out-of-hours" note (p 43)

NB In the text, the clock icons for **Stats-levels 1–3** *are on the right-hand side of the pages as usual. The clock icons on the left-hand side are for* **Stats-level 0** *only.*

(Stats-level 0 only)

DAY 2: THE EXPERIMENT ON RED BEADS

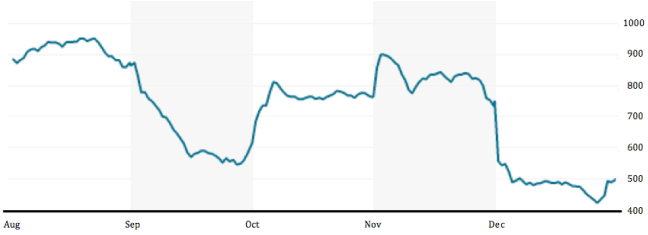
(Stats-level 1–3)

Run charts

Before commencing our study of the Experiment on Red Beads, there is just one "technical" matter to introduce—even for those on Stats-level 0 (or 00)! It is the type of chart known by various names such as a *time series graph* or a *running record* or simply a *run chart*. We'll call it a *run chart*.

A run chart provides a picture of how a value or a measurement etc changes over time. It's the kind of graph often seen in, for example, the Business or Money section of a newspaper or magazine or on the internet. Familiar examples are of a daily stock market index (like America's Dow Jones or Britain's FTSE 100) or of the exchange rate showing the value of, say, the British pound in terms of the American dollar or some other currency. Monthly data, e.g. of a country's unemployment figure or trade balance, can similarly be illustrated on a run chart. Why do we need such pictures? Because they make it a lot easier to see what's going on, often literally "at-a-glance", compared with our just staring at lots of numbers arranged in lists or tables.

Drawing a run chart is straightforward. Of course, with a very large number of data-points such as were used for the run chart alongside, it would also be very tedious! Here we'll generally be dealing with considerably smaller amounts of data, and so it will be feasible to draw our charts by hand.



For illustration, imagine we have just launched a new product on the market, and consider how its monthly sales figures might develop and how the management might interpret those figures.

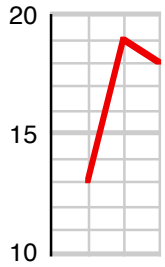
> Despite what can be gained by using pictures rather than lists or tables of numbers, such monthly management data are often interpreted without using run charts. One common method uses pairwise comparisons, the most obvious being the comparison of the current month's figure with the previous month's figure. This comparison is usually expressed on the management report by + or – the actual numerical difference and/or the percentage difference—or both—between the two figures. Percentage differences are often the more popular since, obviously, they express the monthly changes in everything that is being reported *on the same scale*—so, for instance, it is then particularly easy to pick out the largest relative changes without having to do any further arithmetic. Other popular types of comparison relate the current month's figure to the same month in the previous year, or alternatively the YTD (Year-To-Date) figure, i.e. the total for the year so far, compared with the YTD figure as recorded in the same month last year—the comparisons again possibly being expressed as percentages. Obviously, in the case of a new product, there are no figures for last year against which to compare. You may be pleased to know that, during this course, we shall not be using any of the devices just described (other than in this artificial example).

To keep things easy, I'll present the supposed monthly sales figures as simple whole numbers. For example, we might be rounding to the nearest 1,000 sales so that, in the data now to be seen, "13" represents between 12,500 and 13,499 sales of the product during the month. Let's say that the sales figure reported in this way at the end of the first month after the launch is indeed 13. At the monthly management meeting, everybody seems quite happy with this figure, but they are expecting higher sales in Month 2 since the introductory promotional effort will still be continuing throughout that month.

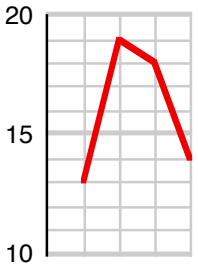
In fact, the Month 2 figure goes up to 19 which (following the small-print description above) is shown on the management report as 19 (+6, +46%). The numbers in brackets indicate that 19 is 6 greater than the previous month's figure of 13 and is approximately 46% greater than that figure. Again, general satisfaction is

expressed at the monthly meeting although there are differing opinions about what will happen in Month 3 since the introductory promotion is now at an end.

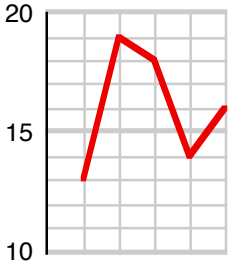
In the same way, Month 3's figure is expressed as 18 (–1, –5%). (18 is 1 less than the previous month's 19 and is approximately 5% less than 19.) This slight decrease is not wholly unexpected since the introductory promotional effort has now ended. Apart from that, there is little comment on the sales figure for this product at the monthly meeting. However, let's now use the three months' figures to start drawing a run chart:



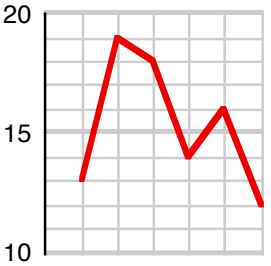
Month 4 is a different story. The figure has suddenly dropped to 14 (–4, –22%). The management all agree that the lack of promotional effort during the past two months is now damaging sales of this product to a really serious extent. If they also look at the run chart, they will see that sales are nearly down to those in the very first month when far fewer people had even heard of the product. Sadly, there is no alternative but to restore the advertising and promotional effort: this product is still not well enough known.



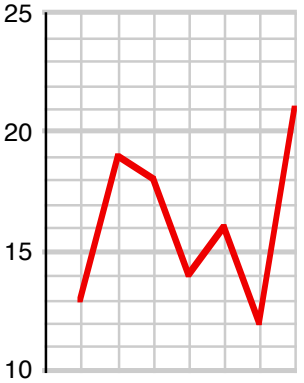
Sighs of relief are audible in Month 5's management meeting. The decline in the sales figure has been reversed by the revitalised promotional effort: the figure has now risen to 16 (+2, +14%). As yet newer products are coming onto the market and thus advertising budgets are under pressure, management decides that this promotion should cease now that the decline has been halted.



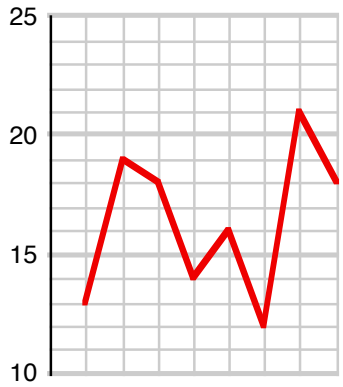
But the sighs of relief are soon silenced. Month 6's figure comes out at a dreadful 12 (–4, –25%)—the lowest figure in the whole six months. Drastic remedies are called for, otherwise this product is destined to be an expensive failure. And so the advertising and promotional efforts are reinstated along with additional price-cuts and other incentives.



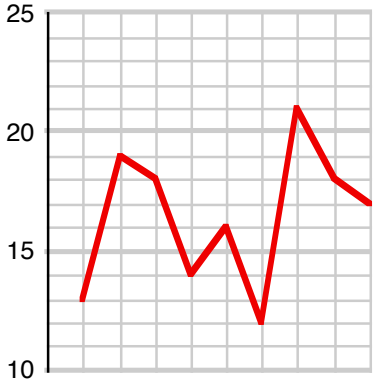
Success! As the result of the exceptional promotional efforts ordered at Month 6's management meeting, Month 7's sales have now soared to an unprecedented 21 (+9, +75%)—getting on for *double* last month's figure! The champagne is flowing!



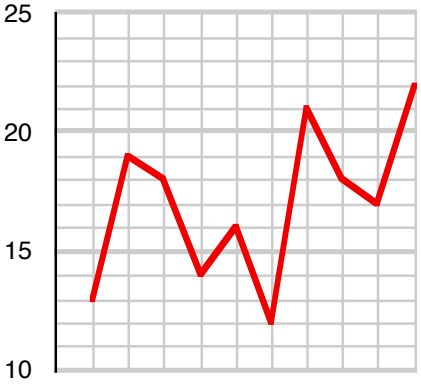
Month 8 shows a mild reduction in the sales figure to 18 (–3, –14%). As previously when a sales promotion came to an end, the managers at their meeting are not too surprised by this relatively slight reduction, recalling the mammoth rise in the previous month (as clearly pictured on the run chart).



Sadly, Month 9's management meeting has no option but to conclude that history is repeating itself. The sales figure is down again, admittedly just to 17 (–1, –6%). But those managers with longer memories (and those who might be looking at the run chart) also recall the 14% drop in the previous month. This cannot be allowed to continue. Yet another price reduction, or advertising campaign, and/or other promotional effort must be actioned.



And it's worked again! Thanks to the renewed, although admittedly expensive, publicity effort, Month 10 has produced the *record* sales figure for this product: 22 (+5, +29%). It really is *so* important to keep a watchful eye on the monthly figure and to act accordingly. Even those who are not just using the month-to-month pairwise comparisons but also checking the run chart can hardly escape a very positive conclusion: after the introductory promotion, the sales of this product had fallen alarmingly but, thanks to management's diligence over recent months, we can now see an impressive upward movement overall.



Now, I repeat that this was just a simple introductory example, purely for illustration to show how easy it is to draw a run chart, i.e. a picture of what otherwise would merely have been just a string of numbers.

Pause for Thought 2–a is also on Workbook page 9.

PAUSE FOR THOUGHT 2–a

Even though these were not real sales figures, and this was not a real management team, do you think that this was a reasonable account of how management might have reacted had these been real sales data?

All I can say is that, in my experience, the answer is Yes! I might comment that the management are going to be awfully busy if they keep acting one way whenever a figure goes up, and another way whenever it goes down—for, except on the odd occasions when the figure stays the same, it *will* always either go up or go down! We'll return to this illustration tomorrow.

INTRODUCTION TO THE RED BEADS EXPERIMENT

It is, of course, more than a quarter-century since Dr Deming passed away. Therefore, those of us who were fortunate enough to have attended one or more of his four-day seminars are now much older than we were then! But, hopefully, not all memories will have faded in the intervening years, in which case there must be very few, if any, who have forgotten about the Experiment on Red Beads.

If you explore the internet, you are likely to find several links to videos involving the Red Beads Experiment. However, most of them, whether or not they feature Dr Deming himself, offer only short extracts from the experiment—nowhere near long enough, in my view, to get any real sense of what actually happened and of the atmosphere in the audience as the experiment ran its course. I have already described something of that atmosphere on Day 1 page 38. So I believe most short extracts miss the point: and that is a real shame in view of the fact that, to many of the delegates, the experiment was a highlight—if not *the* highlight—of the whole seminar. Worse still, such extracts are sometimes accompanied by brief and poorly-scripted coverage which I suggest can literally do far more harm than good.

So if, some time after you've worked through today's material, you feel you'd like to spend some money on the experiment, my recommendation is to definitely stick to what the Deming Institute (www.deming.org) has to offer. Firstly, *The Deming Library* contains a couple of enjoyable and instructive videos. On Volume 7: "The Red Beads and Life" you will see some good extracts of the experiment carried out at one of Dr Deming's four-day seminars. Then, in Volume 8: "Lessons of the Red Beads Experiment", Dr Deming talks about some of the learning which comes from the experiment in general and, in particular, from the set of results generated at Volume 7's four-day seminar. Again, these videos are rather short but they are nevertheless well worth watching. On the other hand, if you have a larger amount of money to spend, more recently the Institute has added to their collection "The Experiment with the Red Beads" and "Analysis of the Red Beads Experiment", both nearly an hour long. That's more like it! In the "real thing", Dr Deming would take well over an hour carrying out the experiment, and there would then be considerable debate and discussion on what the delegates had seen and experienced, often continuing into the afternoon. Thus, as with the four-day seminars themselves, Dr Deming was wise enough to allocate sufficient time for the learning to really begin to penetrate: it is a waste of time to attempt it either superficially or in a hurry.

So, in total contrast to all the video material mentioned, we shall now spend the whole of the rest of today with the Experiment on Red Beads! And I will do my best to make it "live" for you, even to the extent of giving you the opportunity to gain experience at playing the part of the lead role in the experiment, that of the Foreman. In the original version, this part was (as you would expect) played by one Dr W Edwards Deming. It is not the only time in this course that I shall ask you to take over his role!

However, before we begin, here's a warning. I first read about the Experiment on Red Beads at least three years before I first saw it carried out at Dr Deming's London four-day seminar in 1985. My initial reading was from his *Quality, Productivity, and Competitive Position* in 1982. And the truth is that I was singularly unimpressed! I stayed that way throughout those intervening three years—so much so that, at that four-day seminar in 1985, the Red Beads Experiment was the one part of the week to which I was not at all looking forward. Quite frankly, I thought it would just be a big bore, because it was so *trivial*: it was so *obvious* what was going to happen. Maybe it didn't help that, on page 142 of *Quality, Productivity, and Competitive Position*, Dr Deming himself literally referred to the experiment as "stupidly simple", a description that he later repeated on *Out of the Crisis* page 299[350]. And, in some senses, it is.

But don't let that fool you—like it did me ...

So what happened at the seminar?

After the delegates returned from their coffee-break on the Wednesday morning, Dr Deming briefly introduced the experiment. Then there was some pleasant humour as he recruited ten members of the audience to join him on stage for the experiment—with him already pre-selected as the Foreman. The ten consisted of six "Willing Workers", three people to form an Inspection Department (a Chief Inspector and two junior inspectors), and a Recorder whose job was to sit at the overhead projector and write down the data representing the workers' performances and to carry out some simple arithmetic.

The Foreman (Dr Deming) then gave the Willing Workers some basic training on their task in preparation for their getting down to the real work—at which, as we shall see, they would (of course) be rewarded or punished according to how well or badly they performed—macho-management at its finest!

Again being honest with you, I was already feeling quite bored during the training session, even before the "real work" began. Had I not been one of Dr Deming's two official assistants at the seminar, there is little doubt that I would have taken the opportunity offered by this apparently dull part of the seminar to go off to do some shopping or sightseeing. But, in the circumstances, I could hardly do that—seated as I was at the front of the room, in full view of the whole audience and pretty much right under Dr Deming's nose!

So I stayed. But my attention soon began to wander, and before long I was thumbing through the pages of the seminar handout to try to find some more productive way of spending the remaining hour and a half before lunchtime.

Maybe 15 minutes later, I raised my eyes out of the book and casually glanced around the audience. Perhaps unconsciously, I had the sense that something was going on in the room—something that I had not expected and with which, of course, I was wholly uninvolved. To my surprise, I saw that the delegates didn't seem bored at all. On the contrary, their attention was already fixed on what was happening on the stage, and they were beginning to respond to what they were seeing and hearing: smiling, nudging each other, nodding and—gradually—reacting to the results being obtained by the Willing Workers, with enthusiastic applause for the good results and sharp intakes of breath or even catcalls for the poor ones.

At least I can say for myself that I had the humility to realise I was missing something, and so I sat up and started paying attention. Being honest yet again, I confess that I *still* saw very little of significance in what was going on, try as I might. You see, as you know, I already had my mind made up—negatively—about the Experiment on Red Beads. I really didn't think I had anything to learn. And, several months later, when recalling this experience, I realised the absolute truth of something which I subsequently pointed out to many hundreds of my own delegates:

UNlearning* is far more difficult—and painful—than *learning.

Now, before we get into the details of the Red Beads Experiment, I'll ask you to take some time on a couple of important Pauses for Thought. I wish that, on that occasion in 1985, my mind had been working in the way exemplified in these Pauses for Thought. Maybe then my little grey cells would have been more attuned to what was really going on! Thus my reason for inserting these two Pauses here is to ensure that you are more ready for the learning than I was.

Pause for Thought 2–b is also on Workbook page 10.

PAUSE FOR THOUGHT 2–b

As we grow older, and hopefully wiser, we may think about several things quite differently from the way that we used to. So identify something that you now regard very differently from the way that you did back in your younger days. *(If you are still very young then you might like to find an older friend to share some thoughts and experiences with you here.)*

Why did you originally think about it in the way that you did?

What made you change your mind?

Was the experience of changing your mind difficult—and painful?

(For my discussion see Appendix page 7.)

In his book: *The Discoverers*, Daniel Boorstin wrote as follows:

> "The greatest obstacle to discovering the shape of the earth, the continents, and the oceans was not ignorance but the illusion of knowledge."

Your answer to the first of the questions in Pause for Thought 2–b was surely something of the nature of "illusion of knowledge"—it certainly was in my case! So at least note the comforting thought from Daniel Boorstin that this doesn't imply you or I are, or were, ignorant!

Pause for Thought 2–c is also on Workbook page 11.

PAUSE FOR THOUGHT 2–c

What are some ways we can acquire and suffer from "illusion of knowledge"?

Should we be wary of them?

(For discussion, again see Appendix page 7.)

A BRIEF OVERVIEW

Let's now move on to a more comprehensive description of the Experiment on Red Beads. I will try to make it come alive for you as much as possible as the day progresses. First, I'll introduce the experiment as I used to carry it out, which differs in only minor detail from Dr Deming's original. (You will soon appreciate, I think, that some of my description here might be described as rather "tongue-in-cheek"!) For illustration I shall use a set of results obtained by the Willing Workers in a company on the West coast of Ireland where I had been invited to present a seminar. Later today I will show you some other sets of results.

After we have worked through the experiment as it happened in Ireland, I shall need to give you some practice! One way for you to get some practice would be to acquire the equipment for the experiment from a supplier such as SPC Press in Knoxville, Tennessee; and then find ten friends to work through the experiment with you. But that might be asking rather a lot! So instead, what I shall do at that stage will be to develop the set of results described in *DemDim* Chapter 6, and give you the opportunity to respond to those results in the role of the Foreman. You can then compare your reactions to those described in the book. (So don't look at *DemDim* Chapter 6 right now or else you'll spoil my carefully-laid plan!)

10 VACANCIES

(educational requirements minimal)

1 RECORDER	— able to write neatly and to perform simple arithmetic
1 CHIEF INSPECTOR	— able to compare figures and to speak in a loud, clear voice
2 JUNIOR INSPECTORS	— able to count (perhaps up to 20) and to write clearly
6 WILLING WORKERS	— no education needed; training provided. Willing and able to obey orders without question or argument.

(There is one position already filled, that of FOREMAN. Dr Neave is the foreman, because he is the only one that knows the job.)

First, a brief overview. As we've seen, the seminar leader (me) plays the role of Foreman, and my first task is to recruit the ten volunteers. On the left is a copy of my recruitment advertisement which was displayed on-screen to that audience in Ireland.

Referring back to my comment on the reverse of today's ID page, the distortion was particularly bad on this recruitment advertisement. Indeed in this case even the printed copy was virtually unreadable. I have therefore needed to re-create the image. There are very minor differences between the original and what appears above but they are merely cosmetic.

The second of the two sentences in the qualifications for Willing Workers in my recruitment advertisement would sometimes elicit mutterings from delegates such as “Sounds like our place”!

The volunteering Willing Workers are to be employed in the finishing stages of a complex and time-consuming manufacturing operation. Their task is well-defined, and I shall give them some training before letting them loose on the job. Some aspects of the job are described and demonstrated in fine detail during the training. After all, the better that people are trained, the more similarity there will be in the way they carry out their work, and thus the more consistent will be their finished product. And consistency of the finished product, i.e. low variation, is of course an essential contribution to good quality.

A work standard is prescribed: 50 units of production per worker per week. It is important that this standard be achieved and maintained. If production were to fall below this level then management would complain. If production were to exceed this amount then union rules would be violated. Consequently, a special tool has been developed and issued to enable this standard of 50 units to be met without fail (unless a worker seriously disobeys the stipulated procedure).

After the training period, the workers in turn perform their first week’s work. But, despite using the special tool, and despite the comprehensive training that they have just received, the workers make some defective product. So, in order to guide them on what is regarded as reasonable performance, the Foreman declares a quota of 45 good items per worker per week, i.e. no more than five defectives. Of course, subsequently the Foreman congratulates good performance and criticises bad performance—but not too harshly at the moment since this is everybody’s first attempt. A brief *post-mortem* is held at the end of the first week with good and bad features of performance and technique—and maybe attitude of the workers—being compared with each other.

Now that everyone has gained some experience, improvement is expected in the second week. Quite often (about half the time) overall improvement is indeed seen, but usually not to the extent of many of the workers reducing their defectives to the stated quota of five.

Consequently, the time has come for management to make an impact. A severe but objective appraisal of performance is instituted. At the end of the third week, the total number of defectives over all three weeks produced by each worker will be tallied. The three worst workers (i.e. those with the highest total numbers of defectives) will be fired; the best three will be paid overtime to keep up production by taking on two-shift working. “Severe but objective” indeed!

The results produced when the experiment was performed at that company in Ireland were as shown on the next page (it is a copy of the Recorder’s overhead transparency on that occasion). The recorded numbers are the number of defectives made by each person each week and, as you see, the Recorder (whose name was Declan) adds them up and calculates some averages. On the left side, he wrote each worker’s total over the first three weeks: all ready for the appraisal. You will also see that, because of the change to two-shift working in the fourth week, Dec replaced the heading of the final column to refer instead to the second shift in that fourth week.

Pause for Thought 2–d (pages 11–12) is also on Workbook pages 12–13.

PAUSE FOR THOUGHT 2–d

Take a careful look through these results. What main feature occurs to you when comparing the six Willing Workers with each other?

	NAME	WEEK 1	WEEK 2	WEEK 3	WEEK 4	TOTAL SHIFT 2
21	ERNIE	7	11	3	6	6
28	IGGY	10	8	10	13	14
31	RICHARD	11	10	10		
30	MARTIN	11	9	10	10	11
33	ANDREW	12	12	9		
32	PAT	11	15	6		
	WEEKLY TOTAL	62	65	48	60	GRAND TOTAL
	TOTAL SO FAR	62	127	175	235	
		÷6	÷12	÷18	÷24	
	AVERAGE SO FAR	10.3	10.6	9.7	9.8	

INSPECTORS: BRENDA
MARGARET MARY

CHIEF INSPECTOR: JOE

RECORDER: DOC

"ANALYSIS" OF THE RESULTS

The most obvious phenomenon is surely Ernie's remarkably good performance compared with everybody else. His second week was rather disappointing (although that's not difficult to explain—see below). Otherwise, his superiority is plain for all to see. Ernie was the only person in single figures during the first week, when both he and everybody else was carrying out the work for the first time. And, as soon as the forthcoming performance appraisal scheme was announced just before the beginning of Week 3, he turned out the quite exceptional result of only three defectives—half as many as were obtained anywhere else in the whole experiment. Subsequently, during *both* halves of his two-shift working in Week 4, he produced just six defectives, while Iggi and Martin (the other two workers who had managed to hold on to their jobs after their appraisals) were into double figures each time.

But small wonder that Ernie was so good. The truth is that he was the Plant Manager—the most senior of all those present. He had, of course, decided to set a good example by volunteering to play the role of a mere Willing Worker. Maybe, as it turned out, it wasn't that good for morale for him to show up the others with such dramatically superior results!

Let's now take the whole set of results from this run of the experiment and summarise some of the Foreman's reactions and comments. Knowing something of the kinds of performances to be expected in the experiment, the Foreman was naturally immediately impressed by Ernie's first attempt. But, during the rest of Week 1, he became a little irritated by everybody else's double-figure performances. However, he kept reminding himself (and the audience) that this *was* only the first week, and obviously mistakes would be made by the workers while they were getting used to the job. He pointed out several technical errors in the way they were carrying out their work, hoping they would remedy those faults during future weeks.

	NAME	WEEK 1	WEEK 2	WEEK 3	WEEK 4	TOTAL SHIFT 2
21	ERNIE	7	11	3	6	6
28	IGGY	10	8	10	13	14
31	RICHARD	11	10	10		
30	MARTIN	11	9	10	10	11
33	ANDREW	12	12	9		
32	PAT	11	15	6		
	WEEKLY TOTAL	62	65	48	60	GRAND TOTAL
	TOTAL SO FAR	62	127	175	235	
		÷6	÷12	÷18	÷24	
	AVERAGE SO FAR	10.3	10.6	9.7	9.8	

INSPECTORS: BRENDA MARGARET MARY

CHIEF INSPECTOR: JOE

RECORDER: DOC

As we have seen, Week 2 began with that disappointing performance by Ernie. In retrospect, the explanation was clear. Ernie had shown up all of his workmates during the first week by his exceptionally good start. When there is a "creep" on the line it is not unusual for him to be "got at" by the others. Ernie therefore obligingly produced 11 defectives in the second week, the same performance level as had been produced—almost exactly—by all the others during the first week. After that disappointment, the Foreman was pleased to see signs of improvement. Iggi, Richard and Martin all bettered their first week's figures. But then came first a minor, and then a major, disappointment. Andrew repeated the poor score of 12 defectives that he had delivered in the first week—obviously a slow learner compared with the others. And then Pat produced what turned out to be the worst score in the whole experiment. But let us remember that he was standing at the end of the line, with only Andrew for company—and clearly (looking at the results so far, i.e. the first two weeks) *he* was being no good influence!

Thanks to that awful result of Pat's and the "join the club" result from Ernie, total performance in the second week was actually *worse* than in the first week. The time had arrived for stern action by management.

The forthcoming appraisals of performance were announced: people's futures—or otherwise—in this company would be decided on the basis of the total number of defectives they produced over the first three weeks. The impressive effect on Ernie has already been remarked upon—no way was he going to lose *his* job. But we shouldn't have been too surprised—the Foreman had, of course, already marked him out during the very first week as someone with special potential. The Foreman expressed some regret that Iggi, Richard, and Martin, who (remember) had all shown minor improvement previously, did not improve any further—in fact, if anything, they regressed a little. On the other hand, Andrew and Pat who, as we also know, were previously the two worst performers, at long last "got their skates on". They knew that considerable improvement would be necessary if they were to hold on to their jobs. And they both produced it. Unfortunately, in neither case was their improvement quite good enough to get them into the top three.

The Foreman felt very pleased by the results of his strategy and his ability to motivate his people. Look how the total number of defectives decreased in Week 3 as people approached their appraisals. No longer were there over 60 defectives during the week. Now there were less than 50.

The double-time working produced mixed success. Ernie settled down to that commendably steady performance of six defectives in both shifts. Martin carried on with the same kind of performance as previously. Unfortunately, Iggi immediately started producing large numbers of defectives. Maybe he just didn't have the stamina for two-shift working.

At this stage, the experiment was abruptly terminated. Despite everybody's hard work, and the Foreman's efforts to get improved performance out of his people, too many defectives had been produced overall. Manufacture of good product had not been sufficient to keep up with the customer's requirements. The customer had therefore cancelled the contract, and ... "Sorry folks—we're out of business!".

And so the experiment came to an abrupt and unhappy end.

OUR FIRST CONTROL CHART

We have now seen our first set of what were referred to yesterday as "process data" (other than the set illustrated on today's first page). We certainly have a process: meticulously defined by the Foreman during the training period. And we have some time-ordered data from that process: the 24 consecutive numbers of red beads recorded by Dec, the Recorder, in his table on page 11.

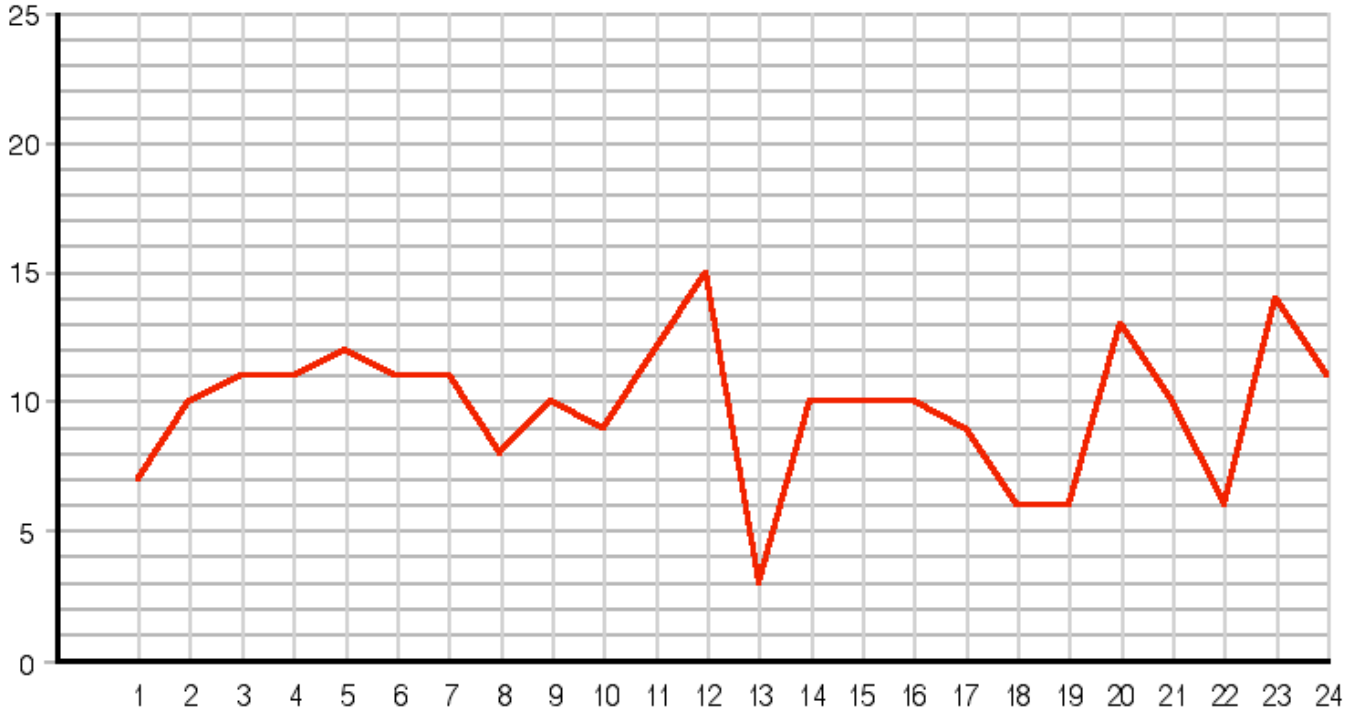
Thus, recalling some of what was introduced on Day 1, it is reasonable to think of developing a control chart of these data. The control chart has a pretty good track-record of telling the truth about a process or, at least, providing guidance on where it is sensible to look for the truth.

So the Recorder in the Red Beads Experiment has a final task to complete: to draw a control chart of the data he has just been recording. Unfortunately, although I retained the tables of data written up by the Recorders at my seminars, I did not retain their control charts. Thus, as I am not able to show you Dec's own control chart, I will now construct it myself.

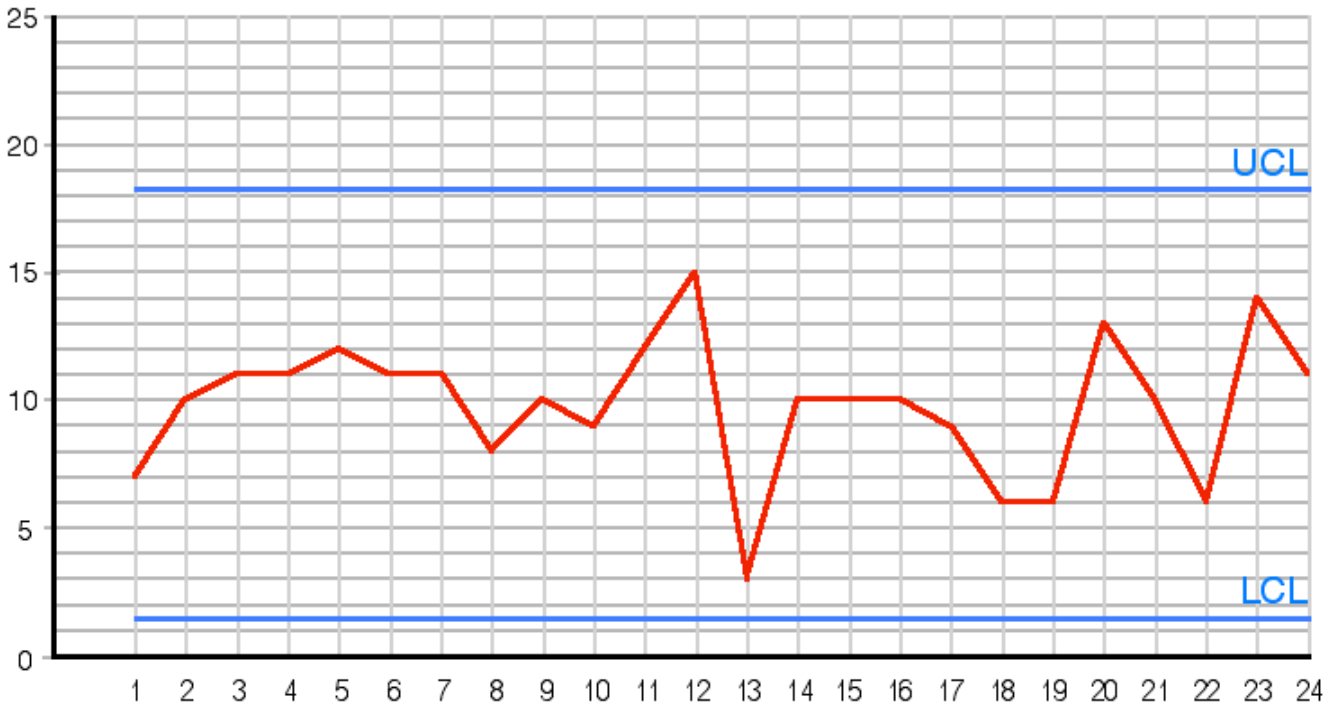
Here again are the numbers of red beads from the experiment, now for convenience printed in time order as a single row rather than the layout in Dec's table:

7 10 11 11 12 11 11 8 10 9 12 15 3 10 10 10 9 6 6 13 10 6 14 11

There are two stages in constructing a control chart. The first stage is simply to draw a run chart of the data; so here it is:



The second of the two stages which then completes the control chart is to place a couple of horizontal lines on the run chart: the *control limits*. The Foreman gave Dec a card on which he had written the method for finding out where these control limits should be drawn. After pressing a few keys on his calculator, Dec came up with the values 1.4 for the Lower Control Limit (LCL) and 18.2 for the Upper Control Limit (UCL). So here is the resulting control chart:



If you have classified yourself at Stats-level 1 or above then there will soon be a couple of Technical Aids which will enable you to compute the control limits shown above. If you are at Stats-level 0 then please don't bother with those Technical Aids: just concentrate on what is *really* important, namely how to *interpret* the chart and what to deduce from it once it has been drawn. That is what follows here.

Let's recall a couple of short extracts from Day 1. Firstly from Day 1 page 5, when discussing what is meant by "understanding variation", we had:

> "In a nutshell, understanding variation is to do with being able to justifiably describe the behaviour over time of processes or systems of any kind by words such as 'stable' and 'predictable' or, on the other hand, 'unstable' and 'unpredictable' … the control chart is *the* invaluable tool which best enables us to discriminate between those two states. The 'official' terms for the two states that you will find both Drs Shewhart and Deming using are respectively 'in statistical control' and 'out of statistical control' although, in the former case, Deming also often refers to a 'stable system'."

And then on Day 1 page 33, to emphasise the point, the ninth of the ten Shewhart "bare bones" was:

> "The purpose of Shewhart's control chart is to help us to discriminate between the two states: is the process in or out of statistical control? Without it, it's often not as easy as it might sound."

Having now seen our first control chart, it won't be difficult for you to guess *how* it helps us to discriminate between the two states. The simplest guidance (which was pretty much all that Dr Deming gave in his seminars) is that if all the points lie between the two control limits then he would judge the process to be in statistical control (stable). Otherwise the indication is that the process may well be out of statistical control, and so then it could be worthwhile to try to identify special causes: the situations where points go outside the control limits will be good places to start looking.

> Now, I rather liken this basic guidance on interpreting a control chart to how you are taught to drive a car in order to pass the official driving test. You obey the speed limits, and you give all the proper signals (whether or not there is anybody behind to see them). However, having passed the test, it is a rare driver

who continues to obey all such rules to the letter—indeed, it can be rather annoying for others to be stuck behind a vehicle whose driver is doing so!

As a second illustration, if you have just bought an electrical or petrol-driven tool to use for woodworking or in the garden, you would probably be wise to start by obeying all the instructions in the leaflet which accompanies the tool. Subsequently however, as you gain experience, you are likely to bend the rules some of the time. The control chart is also a tool, albeit a statistical tool rather than an electrical or petrol-driven one. So tomorrow I'll suggest some thoughts on how you might judiciously amend the basic guidance as you become a more experienced user of this tool.

As a new user of the control chart, here is your obvious Pause for Thought:

Pause for Thought 2–e is also on Workbook page 13.

PAUSE FOR THOUGHT 2–e

What does the control chart on page 15 tell you?

(For brief but very important discussion, see Appendix page 7 one more time.)

Are you startled by what the control chart has just told you? Fear not: all will be revealed!

THE TRUTH, THE WHOLE TRUTH, AND NOTHING BUT …

It is time for me to come clean as to the nature of the "work" in the Red Beads Experiment, and how it is performed. This description is quite lengthy (more than three pages). It divides into roughly equal quarters (the second quarter beginning at "The training, part 1" below). So, in order to get things clear in your mind, I recommend that you read each of the four quarters two or three times before moving on to the next.

Let's begin at the beginning. As I introduced the experiment, I made no secret of Dr Deming's description of it as "stupidly simple"—indeed, I even gave delegates the page reference in *Out of the Crisis*! But I also pointed out to them that, in Dr Deming's work, you often find things which are, at one and the same time, both simple and profound. The purpose of this experiment is to learn—and to have fun: there is nothing wrong with doing both, and indeed Dr Deming was most favourably disposed to that combination! Yes, the experiment contains humour, but it also contains profound messages. The audience will be invited to identify some of those profound messages after the experiment is concluded.

> In the Major Activity near the end of the day, I shall ask you to write a comprehensive account of the messages that you will have learned from the various runs of the Red Beads Experiment introduced and discussed today. You would therefore be wise to start taking relevant notes now and continue to do so during the rest of the day in order to make that task easier for you to carry out when the time arrives.

To help discover the messages, members of the audience are invited to adopt a dual personality whilst the experiment is in progress. At one level, a very superior intelligence could be looking down at the experiment from on high, genuinely understanding absolutely everything there is to know about it. At the other level, the observer could be some inferior creature, e.g. an insect on the floor, with no possibility of comprehending what is going on—the situation is "way over his head".

So the All-Knowing, looking down at the system from on high, has full comprehension of it. But to the Un-Knowing, looking up at it from floor level, it is far too large and complex for him to have any chance of understanding what is happening. Nevertheless, our Un-Knowing does have a brain—a rather special brain for an insect! Let us suppose that the Un-Knowing can recognise numbers, and can interpret them just as well as the average manager, politician, media reporter—or maybe even economist or accountant!

Going by what they see, the delegates will more naturally identify with the "All-Knowing" role. The apparatus for the experiment is most surely "stupidly simple". There is a container half-filled with a large number of beads, differing only (as far as one can tell) in colour. 3,000 of the beads are white and the remaining 750 are red. Then there is a piece of wood or plastic: the so-called "paddle". The paddle has 50 circular depressions sunk into it in a 5×10 pattern. There is also a bucket to help in a mixing operation. The only other apparatus provided is pens and paper and a couple of clipboards for the convenience of the junior inspectors.

The training, part 1

Of the two personalities mentioned above, the Foreman is in the "Un-Knowing" state—although he does not appear to appreciate the fact! In the context of this experiment, that is indeed the more realistic part for him to play. For who *really* fully understands the processes and systems for which they bear responsi-

bility? But, of course, both they and the Foreman in particular can understand and act upon numbers, can't they? There's even an acronym for it: MBR (Management By Results).

The Foreman may point out to the audience that the Inspection Department could appear to be relatively overstaffed: no less than three inspectors for just six Willing Workers. Do we really need half as many inspectors as production workers? The Foreman explains that this is, in fact, advisable because inspection is both a vital and a difficult task. Without accurate inspection data, how can the customer be protected—and how can the workers be compared and judged?

The Foreman now trains the Willing Workers. He checks and confirms that the workers are all prepared to put forth their best efforts to carry out their job as specified (recalling the qualifications stipulated for Willing Workers in the recruitment advertisement on page 9). And so he shows them what to do: their close attention is demanded—not everybody can do this job (as they will soon discover). The job is to make white beads; the customer will not take red. A strictly rigid procedure is defined—in order to avoid variation. Clearly, with a rigidly defined procedure, and appropriate training to learn that procedure, any subsequent variation in performance will then be a worker's own fault. It is assumed that the company is ISO 9000 registered, so there exists full documentation, traceability, accountability, definition of the quality system, a huge reference manual (from which this procedure is taken), etc.

As mentioned earlier, the work standard is 50 items of production per worker per week. In order to help the workers precisely attain this standard, the Foreman will provide the workers with the "paddle" which is illustrated on the previous page. Recall that there are exactly 50 depressions in the top of the paddle.

Before each worker performs the task, a mixing operation is to be carried out, and so this is now demonstrated by the Foreman. It consists of tipping all the beads from the container into the bucket and then back into the container. (The system uses gravity—fortunately a cheap and plentiful resource.) The worker (or, during the demonstration, the Foreman) takes the paddle and places it on the edge of the container, holding it at a specified angle of 44° to the horizontal. The paddle is then gently but firmly pushed into the beads, with its slope allowed to steadily decrease to nearly horizontal. Great care must be exercised during this procedure. The 50 depressions will now be entirely covered by the beads. The paddle should next be raised back to that same angle of 44° with the horizontal. Then, retaining that angle, the paddle is drawn out from the beads. 50 beads will have been caught in the holes in the paddle. There may be some surplus beads sitting on top of the paddle; if so, they must be shaken off by gently tapping the paddle against the sides of the container. It is vital that the paddle be raised to 44° *before* withdrawing it from the beads—for otherwise there may soon be some beads rolling around the table and onto the floor.

The training, part 2

The 50 beads are the workers' production for that week, the white and red beads being good and bad product respectively. Having demonstrated the operation himself, the Foreman takes the paddle over to the workers to show them what he has produced. He points out his large majority of good white product, and also states that he has included just a few defective red product so that they can see and be clear about what they need to avoid making.

The Foreman then takes the paddle over to the Inspection Department, so that both the junior inspectors and the Chief Inspector can learn their jobs. Inspection can be a tedious operation, thus increasing the chance of human error. He therefore gets the two junior inspectors, independently of each other, to count and write down the number of red beads they see in the paddle. The Chief Inspector then compares their two results. There are, of course, two possibilities: the two numbers may be the same or they may be different. If the numbers are different, a mistake has been made. If the numbers are equal, it is possible that *two* mistakes have been made! However, for the purposes of this experiment, such *independent* agreement between the two junior inspectors provides an operational definition (discussed on Day 11) of the

number of red beads to be reported and recorded. (Dr Deming often pointed out that this independence of the two counts is about the only thing that management gets right in the whole experiment! If you're interested in why, see the paragraph in the middle of *DemDim* page 107.) Accordingly, if the numbers are not the same, the two junior inspectors are told to try again, still independently of each other—as often as necessary to obtain agreement. When their two numbers agree, the Chief Inspector reports that number of defectives to both the Foreman and the Recorder.

The 50 beads are then returned to the container in order that the working conditions remain the same for everybody (for how else could their results be fairly compared with each other's?).

Now that both the inspectors and the workers have received their training, we are nearly ready for the real work to commence. Before that, the Foreman has a few final words of encouragement for the workforce. First, so that they know what is expected of them, he sets the goal of no more than five defectives out of their 50 items. Next, he makes clear to each of them that the future of their job depends upon their performance. Do they understand that there is a lot of competition for this work? Every week may be their last on this job. He is (of course) looking for results. From now on (recalling again that the recruitment advertisement stipulated the Willing Workers must be willing and able to obey orders without question or argument) there will be no talking, no comments, no backchat, no questions. They are simply to do their jobs as they have now been trained. They are not allowed to resign. But, of course, anybody who performs badly or who violates the instructions, etc, may be "let go".

Oh, and finally, he wishes them good luck and trusts that they will enjoy their work!

The "real work"

And so the real work commences. The workers come forward, one by one, to carry out their task under the watchful eye of the Foreman. He looks out for things to criticise. The initial angle may be wrong; the action may be jerky, or too fast, or too slow; the paddle may be lowered at the wrong rate; the paddle may not be inserted far enough into the container; the withdrawal angle may be wrong; instead of "gently tapping" the paddle to get rid of any surplus beads, the action may be too rough; the worker might try to tip the paddle, or shake it up and down rather than side to side. Of course, if the worker produces very few red beads, perhaps even meeting the quota of five or less, the Foreman instead congratulates the worker's care, concentration and obedience to the details of the procedure.

In the case of such a good result being announced by the Chief Inspector, the audience often automatically applauds and cheers even before the Foreman has the chance to offer his praise. And, on the other hand, a high score (such as Pat's at the end of the second week) may be greeted by good-humoured derision or even, on occasions (rather depending on how the Foreman is acting his part), by some genuine feelings of embarrassment.

As you will have realised some time ago, no worker has much control over the results which he produces! Most would agree that he actually has none at all; others might argue that, by some judicious steering of the paddle into the container, he could conceivably be able to influence the result just a little. Whichever is the case, it is clear to all that the Experiment on Red Beads is an elaborate charade. Just about everything that is said and done in the production process is irrelevant to the results obtained. But that's from the viewpoint of the All-Knowing ... . From the Un-Knowing level, there is *no suspicion* of it just being a charade. Everything that happens and everything that is said seems eminently reasonable. *Of course* it is sensible to define a rigid procedure so as to reduce variation by permitting no deviation. *Of course* the workers should be trained to carry out the work with discipline and consistency. *Of course* it is wise to specify how each phase of the operation is to be carried out. *Of course* it makes sense to set quotas. *Of course* it is right to criticise poor results and praise good ones. *Of course* it is necessary to appraise performance. *Of course* it is justifiable to fire workers with the worst results. *Of course!*

But now here's a different "Of course". Of course, if our Un-Knowing friend wasn't *totally* unknowing, but had one special piece of knowledge, he might stand a chance of realising that those thoughts in the previous paragraph are all nonsense—even without understanding any technical details of the work at all. What would that special piece of knowledge be? *How to draw a control chart and interpret it.*

We have already seen on page 15 the control chart for the results recorded by Dec, and what it tells us in the Pause for Thought 2–e. (If you need reminding, look again at the bottom of Appendix page 7.) Now, if we slip into the role of the All-Knowing, we *know* that what the control chart told us is surely true. How *could* this process of drawing 50 beads out of the container be anything other than in statistical control, i.e. stable? In fact, it must be one of the most stable processes imaginable! So it is indeed true that, as was stated in the Appendix, "essentially all the variation in the results is due to common causes, to the system, *not* in any way to the Willing Workers". *The control chart has told the Un-Knowing what the All-Knowing already knew to be true!* In most practical situations, of course, we do not have the benefit of the All-Knowing's knowledge. So we need to be guided by the control chart's intelligence instead. And it doesn't often let us down.

So let us summarise. If the control chart of data from the experiment indicates that the process is in statistical control then this tells us that effectively all of the variation is coming from the *system*—with the Willing Workers being at the mercy of that system. When they carry out their task, the fact is that whether they get a good result or a bad result is merely a matter of *luck*. Should we praise them for simply being lucky? Should we criticise them for being unlucky? What use could it be to appraise their performance when the variation comes from the *system*? None. How could it be justified? It cannot.

The Technical Aids

We have now reached the first of the Technical Aids to be included in Days 2 and 3. Here, Technical Aids 1 and 2 describe how the control limits are computed for control charts that are based on the type of data produced and recorded in Red Beads Experiments. Technical Aid 3 contains a warning that, although control limits for all kinds of data are based on similar reasoning, some of the fine detail will vary according to the particular type of data being recorded. Hence the method described here is *not* generally applicable to many other types of data. This matter will be pursued on Day 3.

Let me remind you that those who have opted for Stats-level 0 are invited to skip the Technical Aids! Thus, if you have elected to be on Stats-level 0 (or 00), please now move straight on to page 22.

Technical Aid 1

One of the earliest applications of Shewhart's invention of the control chart was for batch inspection of mass production processes. In such inspection, samples (batches) of n items from the process's output are regularly drawn and inspected, and the number X of defective items recorded. After several samples have been inspected, the control limits are computed as follows.

Using the statistician's traditional shorthand for averages, $\bar{X}$ represents the average number of defectives found in the samples so far, while $\bar{p} = \bar{X} \div n$ is the average *proportion* of defectives in those samples. Shewhart's guidance about control limits then leads to the upper and lower limits being placed at

$$\text{UCL} = \bar{X} + 3\sqrt{\bar{X}(1-\bar{p})} \quad \text{and} \quad \text{LCL} = \bar{X} - 3\sqrt{\bar{X}(1-\bar{p})}\,.$$

See if you can use this method to obtain the control limits quoted on page 14 and drawn on page 15. Use all 24 numbers of red beads in your calculation. (If you need help, the computations are sketched out in Technical Aid 2 on the next page—but try it by yourself first in the space at the top of the page or in the Workbook.)

Space has also been left for these computations at the top of Workbook page 14.

Technical Aid 2

Firstly, notice that Dec recorded the total number of red beads obtained in the experiment near the bottom right of his table on page 11: it was 235. But now you'll need your calculator.

The average number of red beads obtained by the Willing Workers was $\bar{X} = 235 \div 24 = 9.792$.

Since the paddle contained $n = 50$ beads each time, the average *proportion* of red beads was $\bar{p} = \bar{X} \div n = 9.792 \div 50 = 0.1958$ which gives $1-\bar{p} = 0.8042$.

So $\bar{X}(1-\bar{p}) = 9.792 \times 0.8042 = 7.8747264$ and $\sqrt{\bar{X}(1-\bar{p})} = \sqrt{7.8747264} = 2.8062$.

Finally, the distance from $\bar{X}$ out to the two control limits is $3\sqrt{\bar{X}(1-\bar{p})} = 3 \times 2.8062 = 8.419$. This gives the upper and lower control limits as $\text{UCL} = \bar{X} + 3\sqrt{\bar{X}(1-\bar{p})} = 9.792 + 8.419 = 18.21$ and $\text{LCL} = \bar{X} - 3\sqrt{\bar{X}(1-\bar{p})} = 9.792 - 8.419 = 1.37$.

Technical Aid 3

If during Day 1 you read the discussion in the Appendix about the first paradox then you may recall Dr Deming's mention of Shewhart's "3σ-limits" (σ is a Greek letter, pronounced "sigma"). The control limits that you have just computed follow Shewhart's guidance by using $\sigma = \sqrt{\bar{X}(1-\bar{p})}$. The reason for this particular choice when the data come from batch inspection as in the Red Beads Experiment will, I'm afraid, have to be reserved for pages 85–88 in the Optional Extras section.

As mentioned earlier, it is important to emphasise that this particular choice of σ does *not* apply to many other kinds of process data. A method that can be employed much more generally will be used tomorrow and is also introduced, discussed and illustrated in the Springboard article (cited on Day 1 page 8).

YOUR TURN

I well remember that, the first few times I was preparing to run the Red Beads Experiment in public, I felt rather nervous. Wouldn't you—knowing that you (as the Foreman) were going to be spending an hour or more just talking about 24 as-yet-unknown *random numbers* (or as near random as makes no difference)? But I soon found out that it could hardly be easier! Whatever numbers turn up, it's so simple to find "reasons" for them. Of course it is: we are well-practised at the art. We do it every week, month, quarter, half-year, year, in our management reports, with production figures, sales figures, financial figures. Financial commentators do it every day—or even every hour or less, e.g. regarding the movements of stock market indices and exchange rates. I'm not saying that all the reasons reported are wrong. I am pointing out that, *whatever* are the results, we and they come up with reasons—whether there actually are any or not! Even on a day when, say, the stock market index hardly moves, a reason is given for that! Few bosses or customers are yet ready to hear explanations just versed in terms of *common*-cause variation. Therefore they are given *special*-cause explanations all the time, for every result. What clearer contradiction in terms could there be? Yes, *of course* the Foreman praises a lower number of defectives. *Of course* he criticises a larger number. *Of course* he remarks on consistent performance. *Of course* he remarks on erratic performance. *Of course* he complains if the target isn't being met. *Of course!*

Now comes the time for you to get some practice at playing the role of the Foreman! Remember that the Foreman (pretends that he) is in the Un-Knowing state—typified by all the discussion in the so-called "Analysis" of the results on pages 12 and 13. So, to help you get ready to perform in that role, I recommend that you now **go back and re-read that page and a half before continuing here**.

Activity 2–f (pages 22–27) is also on Workbook pages 14–19.

ACTIVITY 2–f

The next four pages show you, one at a time, the results from the Red Beads Experiment illustrated in *DemDim* Chapter 6.

There is space for you to insert indications of your reaction to the number of red beads obtained at each stage. Naturally, you could say even more if the experiment were "live": you could *see* things to congratulate or criticise about the way the Willing Workers are carrying out their task (wrong angle, or too fast, or too slow, or too unsteady …). But there's still plenty that can be said in response to the figures alone!

To get you started, I have included my suggestions of reactions to the first four figures—they are very much the kind of comments that you might have heard from Dr Deming himself. See how you get on with the rest of the experiment. If, after some thought, you need extra help then I've given a few further suggestions on page 27.

NB The version of the experiment in *DemDim* Chapter 6 is Dr Deming's. I should therefore mention three minor differences between his version here and my version which is otherwise being illustrated today:

- Dr Deming referred to the time period for each set of results as a day rather than a week.
- Although he would carry out a performance appraisal and fire the three workers who had produced most red beads, he did this after the fourth day rather than the third.
- For consistency with my own version of the experiment (which produces 24 items of data in all) I have not included the final week's data here (nor in *DemDim)* which were obtained by the three "best" workers: Ed, Al and Audrey.

DAY 1

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16				
John					
Al					
Carol					
Ben					
Ed					
Daily Totals					

"What a terrible start! But you've only just been trained—weren't you watching?"

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16				
John	9				
Al					
Carol					
Ben					
Ed					
Daily Totals					

"That's better."

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16				
John	9				
Al	4				
Carol					
Ben					
Ed					
Daily Totals					

"Excellent: continuous improvement."

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16				
John	9				
Al	4				
Carol	7				
Ben					
Ed					
Daily Totals					

"What a disappointment."

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16				
John	9				
Al	4				
Carol	7				
Ben	9				
Ed					
Daily Totals					

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16				
John	9				
Al	4				
Carol	7				
Ben	9				
Ed	9				
Daily Totals	**54**				

DAY 2

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10			
John	9				
Al	4				
Carol	7				
Ben	9				
Ed	9				
Daily Totals	**54**				

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10			
John	9	11			
Al	4				
Carol	7				
Ben	9				
Ed	9				
Daily Totals	**54**				

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10			
John	9	11			
Al	4	9			
Carol	7				
Ben	9				
Ed	9				
Daily Totals	**54**				

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10			
John	9	11			
Al	4	9			
Carol	7	11			
Ben	9				
Ed	9				
Daily Totals	**54**				

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10			
John	9	11			
Al	4	9			
Carol	7	11			
Ben	9	17			
Ed	9				
Daily Totals	**54**				

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10			
John	9	11			
Al	4	9			
Carol	7	11			
Ben	9	17			
Ed	9	7			
Daily Totals	**54**	**65**			

DAY 3

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7		
John	9	11			
Al	4	9			
Carol	7	11			
Ben	9	17			
Ed	9	7			
Daily Totals	**54**	**65**			

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7		
John	9	11	12		
Al	4	9			
Carol	7	11			
Ben	9	17			
Ed	9	7			
Daily Totals	**54**	**65**			

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7		
John	9	11	12		
Al	4	9	13		
Carol	7	11			
Ben	9	17			
Ed	9	7			
Daily Totals	**54**	**65**			

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7		
John	9	11	12		
Al	4	9	13		
Carol	7	11	14		
Ben	9	17			
Ed	9	7			
Daily Totals	**54**	**65**			

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7		
John	9	11	12		
Al	4	9	13		
Carol	7	11	14		
Ben	9	17	9		
Ed	9	7			
Daily Totals	**54**	**65**			

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7		
John	9	11	12		
Al	4	9	13		
Carol	7	11	14		
Ben	9	17	9		
Ed	9	7	12		
Daily Totals	**54**	**65**	**67**		

DAY 4

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7	6	**39**
John	9	11	12		
Al	4	9	13		
Carol	7	11	14		
Ben	9	17	9		
Ed	9	7	12		
Daily Totals	**54**	**65**	**67**		

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7	6	**39**
John	9	11	12	10	**42**
Al	4	9	13		
Carol	7	11	14		
Ben	9	17	9		
Ed	9	7	12		
Daily Totals	**54**	**65**	**67**		

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7	6	**39**
John	9	11	12	10	**42**
Al	4	9	13	11	**37**
Carol	7	11	14		
Ben	9	17	9		
Ed	9	7	12		
Daily Totals	**54**	**65**	**67**		

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7	6	**39**
John	9	11	12	10	**42**
Al	4	9	13	11	**37**
Carol	7	11	14	11	**43**
Ben	9	17	9		
Ed	9	7	12		
Daily Totals	**54**	**65**	**67**		

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7	6	**39**
John	9	11	12	10	**42**
Al	4	9	13	11	**37**
Carol	7	11	14	11	**43**
Ben	9	17	9	13	**48**
Ed	9	7	12		
Daily Totals	**54**	**65**	**67**		

	Day 1	Day 2	Day 3	Day 4	Totals
Audrey	16	10	7	6	**39**
John	9	11	12	10	**42**
Al	4	9	13	11	**37**
Carol	7	11	14	11	**43**
Ben	9	17	9	13	**48**
Ed	9	7	12	7	**35**
Daily Totals	**54**	**65**	**67**	**58**	**244**

Here are a few more suggestions:

On Day 2 for Al:	*"You were yesterday's top performer—must have let it go to your head."*
On Day 2 after Ben's 17:	*"Hold it—stop the line!"*
At the end of Day 2:	*"**65?** That's a lot worse than the first week! Quite dreadful."*
On Day 3 for Al:	*"From bad to worse."*
On Day 3 for Ben:	*"I'm glad you learned your lesson."*
On Day 4 for Audrey:	*"You're a slow learner. But I'm proud of you."*
On Day 4 for John:	*"Very consistent. Consistently bad."*

Now, if you haven't done so already, go back and try to complete your remarks for all the remaining results.

(Then, finally, take a look at my complete set of remarks on Appendix page 8.)

After a couple of pages of introduction to the Experiment on Red Beads at the beginning of *DemDim* Chapter 6, the data presented in Activity 2–f are discussed from the top of *DemDim* page 103. So now that you have worked your way through this Activity, I suggest you complete this morning's study by **reading Chapter 6** (it's only eight pages long). This will both consolidate what we have already covered and also perhaps provide you with a few extra points to add to the notes that you are taking to help you with the Major Activity at the end of the day. (As usual, ignore the formulas and computations if you are on Stats-level 0.)

Reference is made during Chapter 6 to the Funnel Experiment since, in *DemDim*, that is covered in the previous chapter. Here we shall be catching up with the Funnel Experiment tomorrow. In fact, in tomorrow's Major Activity, which will occupy almost the entire afternoon, you will be carrying out a full version of the Funnel Experiment (although using different equipment from that described by Dr Deming).

SOME RECOLLECTIONS

In spite of the "stupidly simple" nature of the Red Beads Experiment, and in spite of our naturally having the All-Knowing's perspective on it, emotions can run high. I shall not forget an occasion when, as soon as the experiment had ended, one of my delegates stood up, ashen-faced and with unsteady voice, to confirm that so much of what had just happened, so much of what I (as the Foreman) had said to the workers, so much of the way I had mistreated and abused them, eventually firing some of them for no justifiable reason, had not only all happened to him but to others in his family.

Another memory is from February 1992: the occasion when I took Tony Carter, recently appointed to the position of Secretary General in the British Deming Association, to meet Dr Deming and attend a four-day seminar in Miami. His hand shot up when it was time for volunteers to participate in the Red Beads Experiment, and he became one of the Willing Workers. Imagine how he felt—on stage with Dr Deming in front of some 600 Americans as the new organisational and administrative head of the BDA. *Of course* he wanted to do well. *Of course* he tried hard to follow instructions. But his performance, as measured by his results, was abysmal. In the subsequent issue of the BDA's newsletter, he wrote:

> "The time came to sack the worst three Willing Workers and, sadly, I was one of them. Even though I knew perfectly well it was entirely the result of the system, I could not escape an illogical feeling of failure. The new Secretary General of the British Deming Association had been fired by Dr Deming at our first meeting!"

I know how he felt. I was there. *I* was willing him to do well. I think I finished up feeling as embarrassed as Tony did.

A further recollection comes from one of my seminars later that same year. A delegate pointed out that, had the supplied materials not been of such poor standard, the workers would not have produced so many defectives. I reminded the delegate that these were hard, competitive times. The contract for supply of beads had been put out to tender, and one particular supplier had come up with an exceptionally good price. It was so good that we couldn't afford to turn down such a good bargain, even if maybe his product wasn't quite so good as we could have obtained elsewhere. It was truly "an offer that we couldn't refuse". A second delegate immediately spoke up to confess that he had just used those exact same words back at his company the previous day.

Two particular runs of the Red Beads Experiment stick in my memory despite the fact that they both took place around 30 years ago. They were the experiments which produced the very best total score and the very worst total score that were obtained over approximately 150 experiments carried out with exactly the same Red Beads equipment as I used at the Ireland seminar.

If you were still in the Un-Knowing state, you would probably not be at all surprised to learn where these two sets of results originated. The very best score (a total of just 203 red beads) was obtained by the most elite set of workers I was ever privileged to have participating in the Red Beads Experiment: five departmental heads in the British Government's Central Statistical Office plus one University Professor of Statistics. At the other extreme, the very worst score of 270 red beads was produced on the first of two occasions that I performed the experiment in Madrid, and some people might have doubts about the abilities of Spanish workers. *Hold on—don't take offence at that remark!* The point of this suggestion—and yet a further important message that comes from the Red Beads Experiment—is how easy it is to find data that appear to provide "evidence" to support personal prejudices. Let's take a look at both sets of data.

> As with the experiment in Ireland described on pages 9–16, a "performance appraisal" takes place at the end of the third week; the three "worst" workers are then fired and the "best" workers have to work double time during the fourth week—they will need to produce **two** paddles of 50 beads, not just one!

Here are the professional statisticians' results:

	NAME	WEEK 1	WEEK 2	WEEK 3	WEEK 4		
27	DAVID W.	9	8	10			
26	DAVID K.	6	9	12			
22	FRANK	7	5	10	13 10		
21	REG	8	4	9	7 7		
20	JOHN	9	3	8	8 8		
34	NEIL	11	13	10			
	WEEKLY TOTAL	50	41	59	53		
	TOTAL SO FAR	50	91	150	203		
		÷6	÷12	÷18	÷24		
	AVERAGE SO FAR	8.3	7.6	8.4	8.5		

JUNIOR INSPECTORS: } BRIAN

CHIEF INSPECTOR:

RECORDER: HENRY

As you will quickly deduce, not only was this an unusually elite audience for a Red Beads Experiment—it was also my smallest! The audience consisted of just the six people I've already mentioned, who therefore were all "encouraged" to volunteer as Willing Workers! So, with no further personnel available, I acted as Recorder as well as Foreman. Further, the inspection process had to be carried out in this instance not by the usual team of three inspectors but just by my colleague Brian Read. I suppose I also acted as Chief Inspector, for I did check extremely carefully Brian's counts of the red beads!

As always, there was plenty for the Foreman to talk about. David W. got off to a rather poor start—nearly twice the permitted quota of 5 red beads. But the second Willing Worker, the late Professor David Kerridge (a great friend and colleague), immediately got down to just one above the quota. However, now look at those steadily deteriorating results in the rest of that first week. Maybe they were slow learners and still

didn't quite understand the job. I therefore gave them a brief additional training session before the start of the second week—and observe the vast improvement that resulted (except, that is, for Neil who clearly *never* got the hang of it!).

So then came my announcement of the forthcoming performance appraisal and the fact that the worst three workers would be fired at the end of the third week. This frightened them so much that, mostly, they just couldn't concentrate properly on the job during that third week. The worst performance of all came from Professor Kerridge—but perhaps he'd already decided to seek work elsewhere!

Moving on to the Spaniards below, you can be sure that, in particular, I had some pretty severe words for the "best workers" who so clearly betrayed the trust I had in them during the fourth week after I had fired the others. Just look at these appalling results!

Madrid, 27 November 1989.

	NOMBRE	SEMANA 1	SEMANA 2	SEMANA 3	SEMANA 4	TOTAL
36	~~IGNACIO~~	16	10	10		
34	~~ORLANDO~~	9	10	15		
29	PACO	9	12	8	11 17	
30	Francisco	11	12	7	13 13	
35	~~Tomaso~~	15	9	11		
30	Jesus	11	9	10	13 9	
	TOTAL SEMANAL	71	62	61	76	GRAN TOTAL
	TOTAL A LA FECHA	~~71~~ 71.	133	194	270	
		÷6	÷12	÷18	÷24	
	PREMEDIO A LA FECHA	11.8	11.08	10.77	11.25	

INSPECTORES: JUAN ANTONIO
INSPECTOR PRINCIPAL: PEDRO
REGISTRADOR: JOSE

So now we have yet more of the profound messages which this "stupidly simple" experiment communicates. The emotions raised and havoc wreaked by treating common-cause variation as if it were special-cause variation is one. Then the ease with which one can invent reasons to "explain" random variation is another. Similarly, the ease with which we can find data that appear to confirm what we want to believe or what we want to persuade others about (however idiotic it is) is yet another.

Finally, regarding my recollections, here is a reminder of the one I mentioned on page 22: my understandable nervousness as I approached running the Red Beads Experiment in public for the very first time. I was to be faced with 24 as-yet-unknown random numbers of red beads and would have to comment upon each with little or no hesitation. Would I be able to think of anything to say?

Well, in Activity 2-f you've now had your own initial experience of the same situation, albeit without the pressure of performing in front of a paying audience. In my case, having muddled through that first time, I was nowhere near as nervous the second time; and still less the third time. In fact, I soon found that not only was I beginning to enjoy running the experiment but I was also discovering for myself more and more of those "profound messages" which the experiment can convey. Not only were my audiences learning more from the experiment: so was I.

It is with those experiences in mind that I'll ask you to take on the role of Foreman twice more this afternoon: the two occasions that I've just introduced, first with the elite statisticians and then with the Spaniards in Madrid. Whilst showing you the data, I've already given you a few obvious suggestions about how to react, especially in the case of the professional statisticians. Both of these sets of data present considerable opportunities for the Foreman to be exceedingly eloquent!

There will then remain just two further items on today's agenda. First comes the Major Activity of writing up your comprehensive summary of messages to be learned from the Experiment on Red Beads. So, in preparation for that, keep adding to your list of notes as you now work through the statisticians' and the Spaniards' experiments. Then finally, after the Major Activity, there will be a short Postscript to complete the day.


Activity 2–g (pages 32–37) is also on Workbook pages 20–25.

ACTIVITY 2–g

As you will see, I have reproduced for you below and on the next page the statisticians' data week by week. There is space on the right of the data for your Foreman-like comments on every count of red beads. An advantage of your carrying out this Activity without an audience is that you can have a little time to consider each response rather than having to come up with it "off the top of your head". But don't take too long about it!

NAME	WEEK 1
DAVID W.	9
DAVID K.	6
FRANK	7
REG	8
JOHN	9
NEIL	11
WEEKLY TOTAL	50
TOTAL SO FAR	50
	÷6
AVERAGE SO FAR	8.3

(No good looking in the Appendix for more hints—I've given you plenty of help already!)

NAME	WEEK 1	WEEK 2
DAVID W.	9	8
DAVID K.	6	9
FRANK	7	5
REG	8	4
JOHN	9	3
NEIL	11	13
WEEKLY TOTAL	50	41
TOTAL SO FAR	50	91
	÷6	÷12
AVERAGE SO FAR	8.3	7.6

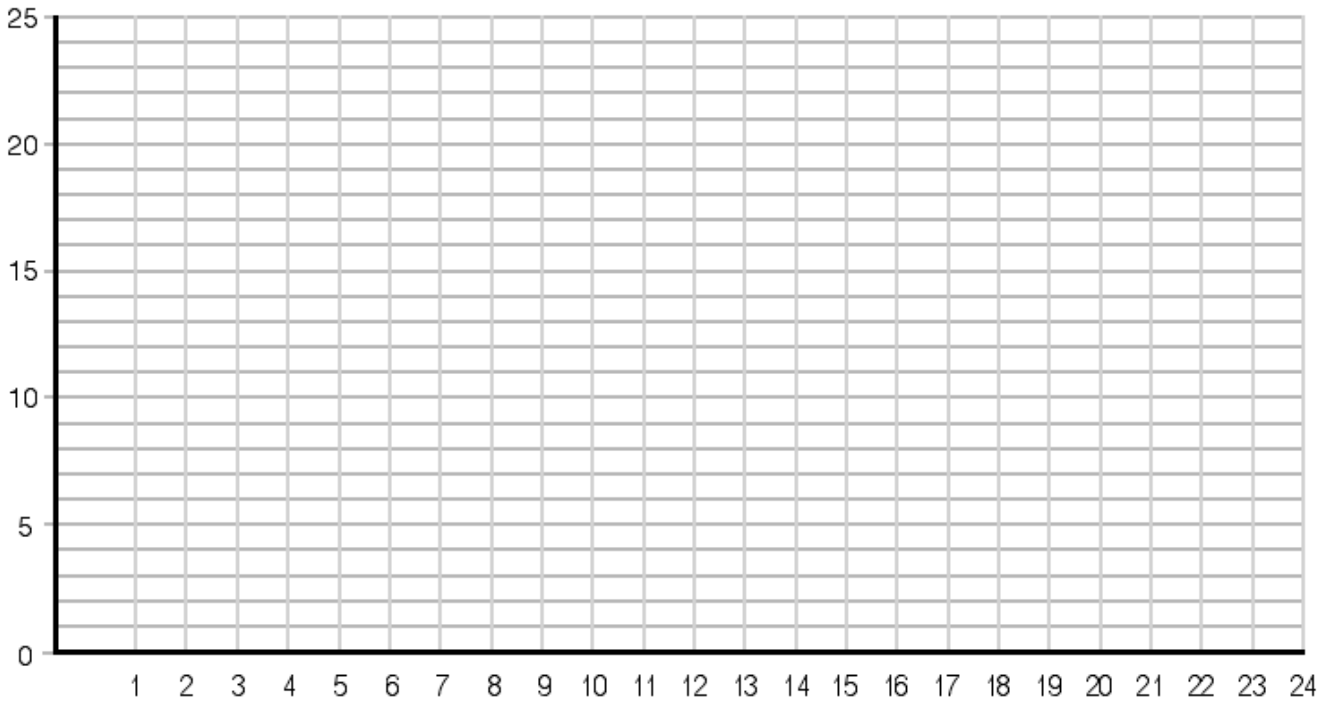
NAME	WEEK 1	WEEK 2	WEEK 3
DAVID W.	9	8	10
DAVID K.	6	9	12
FRANK	7	5	10
REG	8	4	9
JOHN	9	3	8
NEIL	11	13	10
WEEKLY TOTAL	50	41	59
TOTAL SO FAR	50	91	150
	÷6	÷12	÷18
AVERAGE SO FAR	8.3	7.6	8.4

Again recall that, in my version of the experiment, I fired the three "worst" workers after the third week, leaving the other three to work double time in the fourth week. So, checking the table below, the "best" workers, Frank, Reg and John, produced 13, 7 and 8 red beads respectively during their first shift in the fourth week, followed in turn by 10, 7 and 8 in their second shift.

NAME	WEEK 1	WEEK 2	WEEK 3	WEEK 4
DAVID W.	9	8	10	
DAVID K.	6	9	12	
FRANK	7	5	10	13 10
REG	8	4	9	7 7
JOHN	9	3	8	8 8
NEIL	11	13	10	
WEEKLY TOTAL	50	41	59	53
TOTAL SO FAR	50	91	150	203
	÷6	÷12	÷18	÷24
AVERAGE SO FAR	8.3	7.6	8.4	8.5

Next, as I had to do when running the experiment for the statisticians, it's time for you to multi-task! You now take over as the Recorder and draw a run chart of the data. If you need reminding about how to draw a run chart, check back with the run chart of Dec's data on page 14. Also as on that page, so that you don't have to keep looking back, here are the statisticians' counts of red beads in time order:

9 6 7 8 9 11 8 8 5 4 3 13 10 12 10 9 8 10 13 7 8 10 7 8



Finally, insert the two control limits to turn the run chart into a control chart, and then state your conclusions. If you're on Stats-level 0 then simply look up the control limits on Appendix page 8. If you are on Stats-level 1 or higher then compute them in the space below. (If you need reminding about the details, Technical Aid 1 is on page 20.)

(You can check your computations in Technical Aid 4 on Appendix page 9. But try it yourself first!)

Now it's time for you to resume the Foreman's role. Here are the Spaniards' very different data. So please work through them as you did with the statisticians' data. (Remember that these are extracts from the *completed* version of Jose's table; thus ignore the fact that the names Ignacio, Orlando and Tamasa are crossed out since, of course, that did not happen until the end of the third week.)

NOMBRE	SEMANA 1
~~IGNACIO~~	16
~~ORLANDO~~	9
PACO	9
FRANCISCO	11
~~TOMASA~~	15
JESUS	11
TOTAL SEMANAL	71
TOTAL A LA FECHA	~~71.~~
	+8
PROMEDIO A LA FECHA	11.8

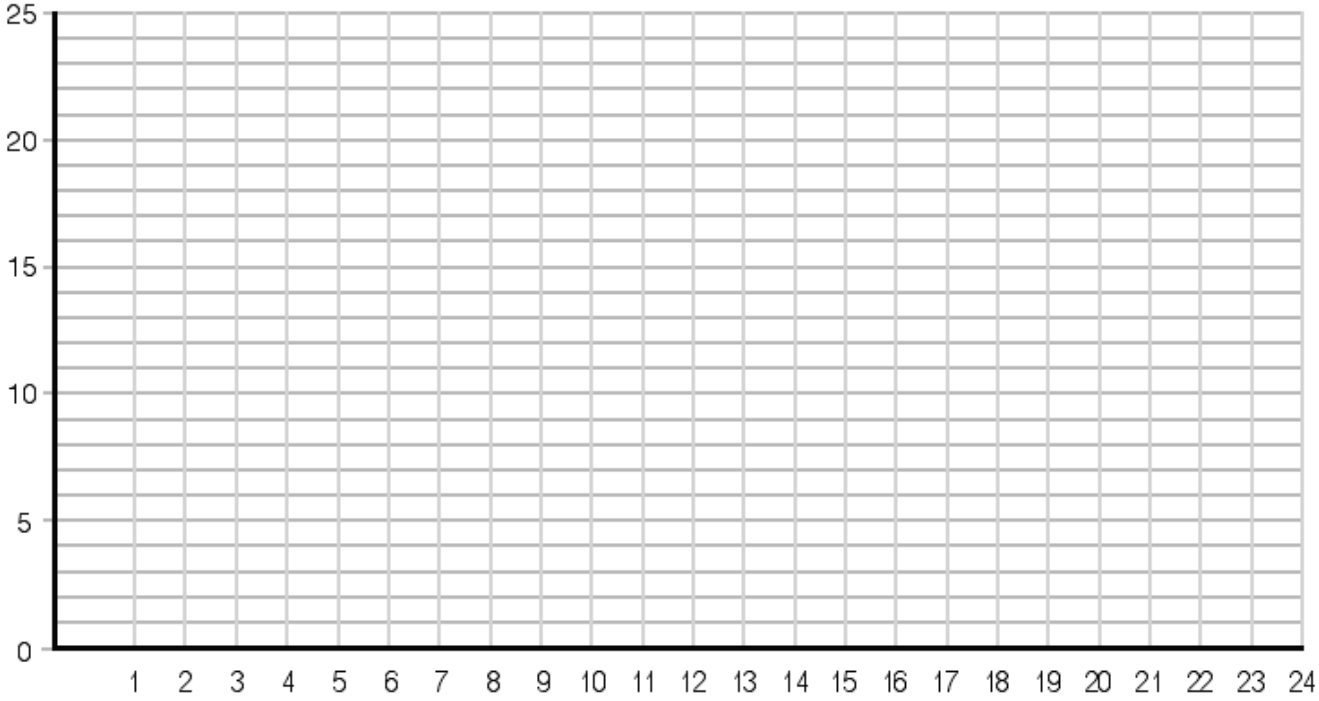
NOMBRE	SEMANA 1	SEMANA 2
~~IGNACIO~~	16	10
~~ORLANDO~~	9	10
PACO	9	12
FRANCISCO	11	12
~~TOMASA~~	15	9
JESUS	11	9
TOTAL SEMANAL	71	62
TOTAL A LA FECHA	~~71.~~	133
	+8	+12
PROMEDIO A LA FECHA	11.8	11.08

NOMBRE	SEMANA 1	SEMANA 2	SEMANA 3
~~IGNACIO~~	16	10	10
~~ORLANDO~~	9	10	15
PACO	9	12	8
Francisco	11	12	7
~~Tomas~~	15	9	11
Jesus	11	9	10
TOTAL SEMANAL	71	62	61
TOTAL A LA FECHA	~~71.~~	133	194
	+8	+12	+18
PROMEDIO A LA FECHA	11.8	11.08	10.77

NOMBRE	SEMANA 1	SEMANA 2	SEMANA 3	SEMANA 4
~~IGNACIO~~	16	10	10	
~~ORLANDO~~	9	10	15	
PACO	9	12	8	11 17
Francisco	11	12	7	13 13
~~Tomas~~	15	9	11	
Jesus	11	9	10	13 9
TOTAL SEMANAL	71	62	61	76
TOTAL A LA FECHA	~~71.~~	133	194	270
	+8	+12	+18	+29
PROMEDIO A LA FECHA	11.8	11.08	10.77	11.25

Finally, return to the Recorder's task of drawing the run chart and then upgrade it to a control chart. Here are the Spaniards' counts of red beads in time order:

16 9 9 11 15 11 10 10 12 12 9 9 10 15 8 7 11 10 11 13 13 17 13 9



As before, insert the two control limits to turn the run chart into a control chart and state your conclusions. Also as before, if you're on Stats-level 0 then simply look up the control limits on Appendix page 8; otherwise compute them in the space below.

(Again the computations are sketched in Technical Aid 4 on Appendix page 9.)

Regarding conclusions from the control charts, they are surely similar to those for Pause for Thought 2–e (on Appendix page 7) except that this time we would presumably comment on statistician John's 3 or Ignacio's 16 and Paco's 17 in similar ways to Ernie's 3—they're *all* within the control limits.

Major Activity 2–h (pages 38–41) is also on Workbook pages 26–29.

MAJOR ACTIVITY 2–h

Hopefully, you now have quite a long list of notes on learning-points from today's Red Beads Experiments, including some from Chapter 6 of *DemDim*.

> At this early stage of the course, you probably do not have access to other sources. But if you do, or will be doing so before long, you may find plenty more messages to write up. Chapter 4 of Mary Walton's *The Deming Management Method* is excellent. Other sources are, of course, Dr Deming's own two books. In *Out of the Crisis* the most relevant pages are 295–302[346–354], although there are several more learning-points from the Red Beads Experiment further on in the book. Chapter 7 of *The New Economics* also describes and studies the Red Beads Experiment and ends with a list of no less than 14 "Lessons from the Red Beads". Deming ends that chapter by innocently remarking: "The reader may perceive Red Beads in his own company and in his own work." Finally, as previously mentioned, my recommended video material is Volumes 7 and 8 of *The Deming Library*.
>
> However, even if you do not have any of these at present, you should by now still be able to produce a quite substantial summary of messages from the Red Beads Experiment.

So first review your notes on all that has happened today. If there were any gaps when you forgot to keep up your note-taking then have a look through the relevant sections and update your notes accordingly.

You may be quite used to trying to convert a collection of notes into a more organised form in preparation for writing up a report or some other kind of document. That is really what you should begin aiming to do here in order that you will finish up with an account which, when you refer back to it in the future, you will find easier to read and learn from.

But first, on Appendix pages 10–12 I have discussed some further messages from the Red Beads Experiment. You might possibly have touched upon one or two of these already, but I think you will also find some new issues in my write-up there. Usually I suggest that you do not turn to my discussions in the Appendix until you have already attempted the relevant Activity. However, in this case it may be better for you to read through that section at this stage. It could give you yet further thoughts to include in your account.

On your return from the Appendix, now spend a little time organising your notes into a small number of groups or categories, i.e. each containing somewhat related matters. Then develop your account of messages from the Red Beads Experiment by writing up a paragraph or two on each of those groups of notes. Finally "top and tail" your account with some appropriate introductory and concluding remarks.

(Page intentionally left blank for your account.)

(continued overleaf)

(Page intentionally left blank for your account.)

In conclusion, now armed with your account, can you think of instances within your work-situation or elsewhere when you have been treated similarly to the way that the Willing Workers have been treated by the Foreman?

Even more importantly, if you are any kind of manager or in any role where you have supervisory responsibilities over others, can you identify situations where *you* have acted like the Foreman?

And, if so, how will your behaviour change from now on?

As I often heard Dr Deming say,

"You could write a book on what can be learned from the Experiment on Red Beads."

Maybe now you've already made a start!

Yes, in some respects the Experiment on Red Beads is indeed "stupidly simple".
But the lessons to be learned from it are not.

POSTSCRIPT

I didn't complete the story about Spaniards' performances in the Experiment on Red Beads. So I should end today by remedying that deficiency.

As indicated on page 28, I presented two seminars in Madrid. On his return to that city, the Foreman could not resist telling the Willing Workers (and the audience) about the awful results obtained on his previous visit. Although the story met with mixed reactions, he was sure that the information would prove to be highly motivational for the new team—they would strive to do better in order to restore national pride. Their results as listed by Jorge were as follows:

	NOMBRE	PRIMERA SEMANA	SEGUNDA SEMANA	TERCERA SEMANA	CUARTA SEMANA	TOTAL
30	JAVIER I	9	10	11		
23	JAVIER II	9	8	6	11	7
19	ANTONIO	2	9	8	9	12
29	MARISA	13	7	9	10	9
31	ALONSO	9	10	12		
37	JOSE	11	14	12		
	TOTAL SEMANAL	53	58	58	58	TOTAL GENERAL
	TOTAL HASTA LA FECHA					
		÷ 6	÷ 12	÷ 18	÷ 24	
	MEDIA HASTA LA FECHA					

INSPECTORES: JOSE MARIA
ANGEL

JEFE DE INSPECCION DE CALIDAD: JESUS

REGISTRADOR: JORGE

These results are certainly rather different from those on my first visit to Madrid. The overall total of red beads (though not stated here by Jorge) was 227—not only much better than in November 1989 but notably better than the average over all my experiments using the same equipment. Further, no doubt as a result of the Foreman's motivational introduction, the first week's performance was pretty good, despite the relatively poor results from Marisa (clearly a slow learner) and Jose (who never quite understood what he

was doing). The first week's commendable total was largely due to the brilliant effort of Antonio who had been particularly incensed by the possible slur about Spanish workmanship that he had perceived in the Foreman's introduction.

So, already by the end of the first week, the pressure was off. No way was this team of Willing Workers going to do anywhere near as badly as the previous Spanish contingent. And so they settled down to producing the rather less exceptional but very consistent overall performance that you see represented in the remaining weeks' totals.

It was, of course, a pity that Antonio did not continue to work anywhere near as hard or as conscientiously as he had in the first week—but he had made his point.

Overall, the Foreman was, of course, immensely satisfied by the way he had motivated, indeed inspired, this workforce to perform so much better than their predecessors.

Of course.

"Wrap-Up Brief" following the Red Beads Experiment

My friend Dave Kerr has presented the Red Beads Experiment numerous times. He has developed a short document which not only summarises some of the learning which comes from it but also looks ahead to several important topics that we shall study later in this course, particularly on Days 8–11. I believe therefore that you might find it interesting to take a look at his "Wrap-Up Brief" now while the experiment is fresh in mind to see some tasters of issues that may not have occurred to you so far. Further, it could also be valuable for you to look back at Dave's summary a number of times during the second half of the course to see how this "stupid experiment" relates to the topics developed there.

I am delighted to be able to reproduce Dave's document on Appendix pages 12–13.

"Out-of-hours" note

As mentioned on page 11 of the introductory Welcome section, you will need to carry out some preparation for your Major Activity on Day 3. It was noted there that this and all such "out-of-hours" tasks are briefly summarised on Appendix page 1. Also, to aid your study on the morning of Day 3, you will find a recommendation in that summary to print in advance a separate copy of Day 3 page 19.

Day 3's Major Activity is a complete version of the Funnel Experiment although it uses different equipment from Dr Nelson's original version. The original version would need much *more* preparation than the version which will be used tomorrow and you would also find that version much more awkward to perform. I recommend that you carry out in advance the necessary preparation rather than leaving it until tomorrow: you will find all the information you need on Day 3 page 36. Either start reading near the top of that page or, for a more comprehensive introduction, go back to the beginning of that section on Day 3 page 35.

To *carry out* Day 3's experiment does not actually need any "previous knowledge": previous knowledge is only involved with *interpreting* the results from the experiment. The experiment itself can be carried out by anyone. But people who, for example, like solving puzzles and/or playing board games will probably take to it better than those who don't. So if you are not an enthusiast for puzzles and board games then why

not invite a friend who *does* enjoy such activities to join you tomorrow afternoon?—it could be more enjoyable for you to have such company during the experiment. And don't forget: you will need to find a couple of standard dice in order for you to play this "silly game"!